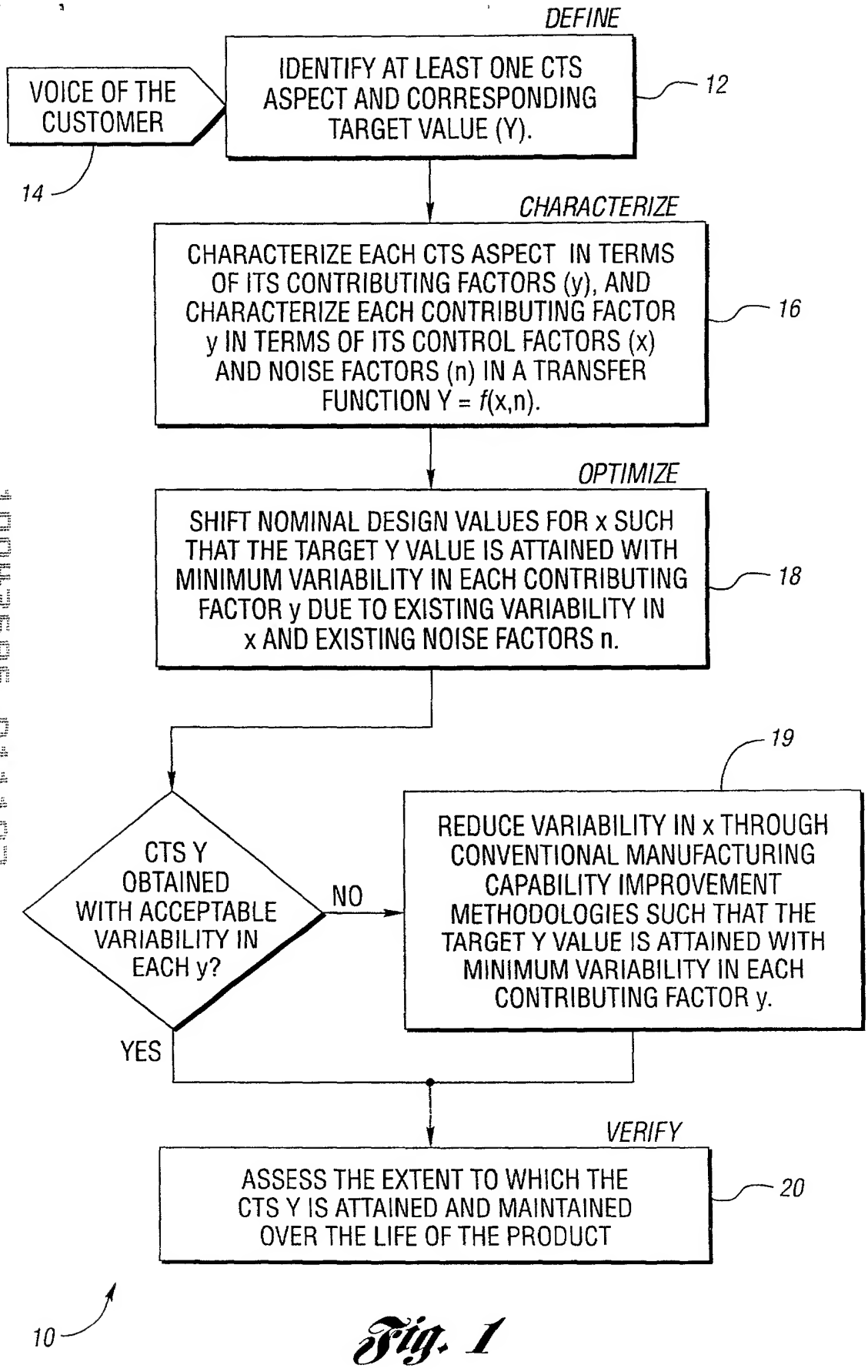

DEFINE
VOICE OF THE CUSTOMER
IDENTIFY AT LEAST ONE CTS ASPECT AND CORRESPONDING TARGET VALUE (Y).
12
14
CHARACTERIZE
CHARACTERIZE EACH CTS ASPECT IN TERMS OF ITS CONTRIBUTING FACTORS (y), AND CHARACTERIZE EACH CONTRIBUTING FACTOR y IN TERMS OF ITS CONTROL FACTORS (x) AND NOISE FACTORS (n) IN A TRANSFER FUNCTION Y = f(x,n).
16
OPTIMIZE
SHIFT NOMINAL DESIGN VALUES FOR x SUCH THAT THE TARGET Y VALUE IS ATTAINED WITH MINIMUM VARIABILITY IN EACH CONTRIBUTING FACTOR y DUE TO EXISTING VARIABILITY IN x AND EXISTING NOISE FACTORS n.
18
19
CTS Y OBTAINED WITH ACCEPTABLE VARIABILITY IN EACH y?
NO
YES
REDUCE VARIABILITY IN x THROUGH CONVENTIONAL MANUFACTURING CAPABILITY IMPROVEMENT METHODOLOGIES SUCH THAT THE TARGET Y VALUE IS ATTAINED WITH MINIMUM VARIABILITY IN EACH CONTRIBUTING FACTOR y.
VERIFY
ASSESS THE EXTENT TO WHICH THE CTS Y IS ATTAINED AND MAINTAINED OVER THE LIFE OF THE PRODUCT
20
10

Fig. 1

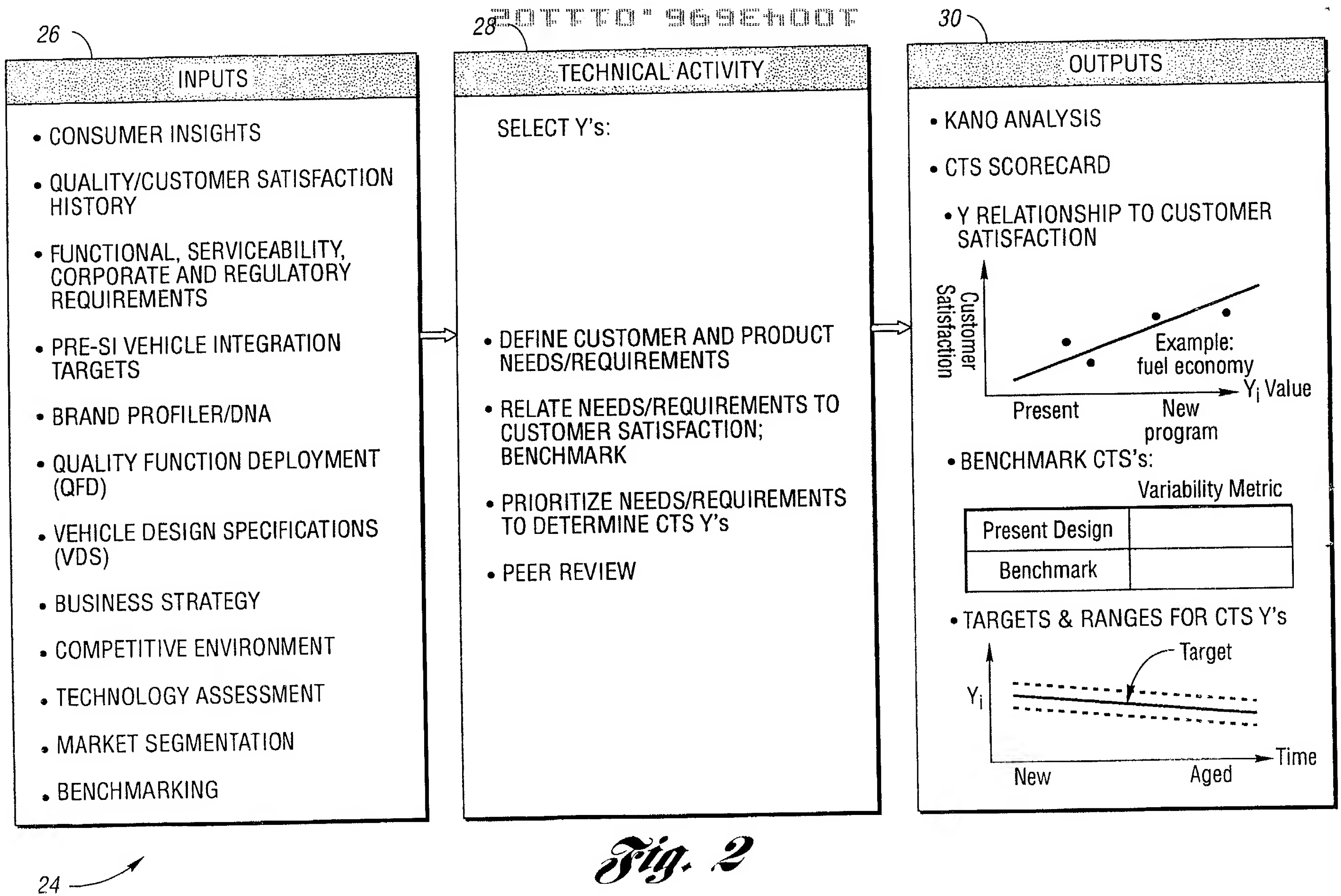

26
INPUTS
• CONSUMER INSIGHTS
• QUALITY/CUSTOMER SATISFACTION HISTORY
• FUNCTIONAL, SERVICEABILITY, CORPORATE AND REGULATORY REQUIREMENTS
• PRE-SI VEHICLE INTEGRATION TARGETS
• BRAND PROFILER/DNA
• QUALITY FUNCTION DEPLOYMENT (QFD)
• VEHICLE DESIGN SPECIFICATIONS (VDS)
• BUSINESS STRATEGY
• COMPETITIVE ENVIRONMENT
• TECHNOLOGY ASSESSMENT
• MARKET SEGMENTATION
• BENCHMARKING
28
TECHNICAL ACTIVITY
SELECT Y's:
• DEFINE CUSTOMER AND PRODUCT NEEDS/REQUIREMENTS
• RELATE NEEDS/REQUIREMENTS TO CUSTOMER SATISFACTION; BENCHMARK
• PRIORITIZE NEEDS/REQUIREMENTS TO DETERMINE CTS Y's
• PEER REVIEW
30
OUTPUTS
• KANO ANALYSIS
• CTS SCORECARD
• Y RELATIONSHIP TO CUSTOMER SATISFACTION
Customer Satisfaction
Example: fuel economy
Y_i Value
Present
New program
• BENCHMARK CTS's:
Variability Metric
Present Design
Benchmark
• TARGETS & RANGES FOR CTS Y's
Target
Y_i
Time
New
Aged
24

Fig. 2

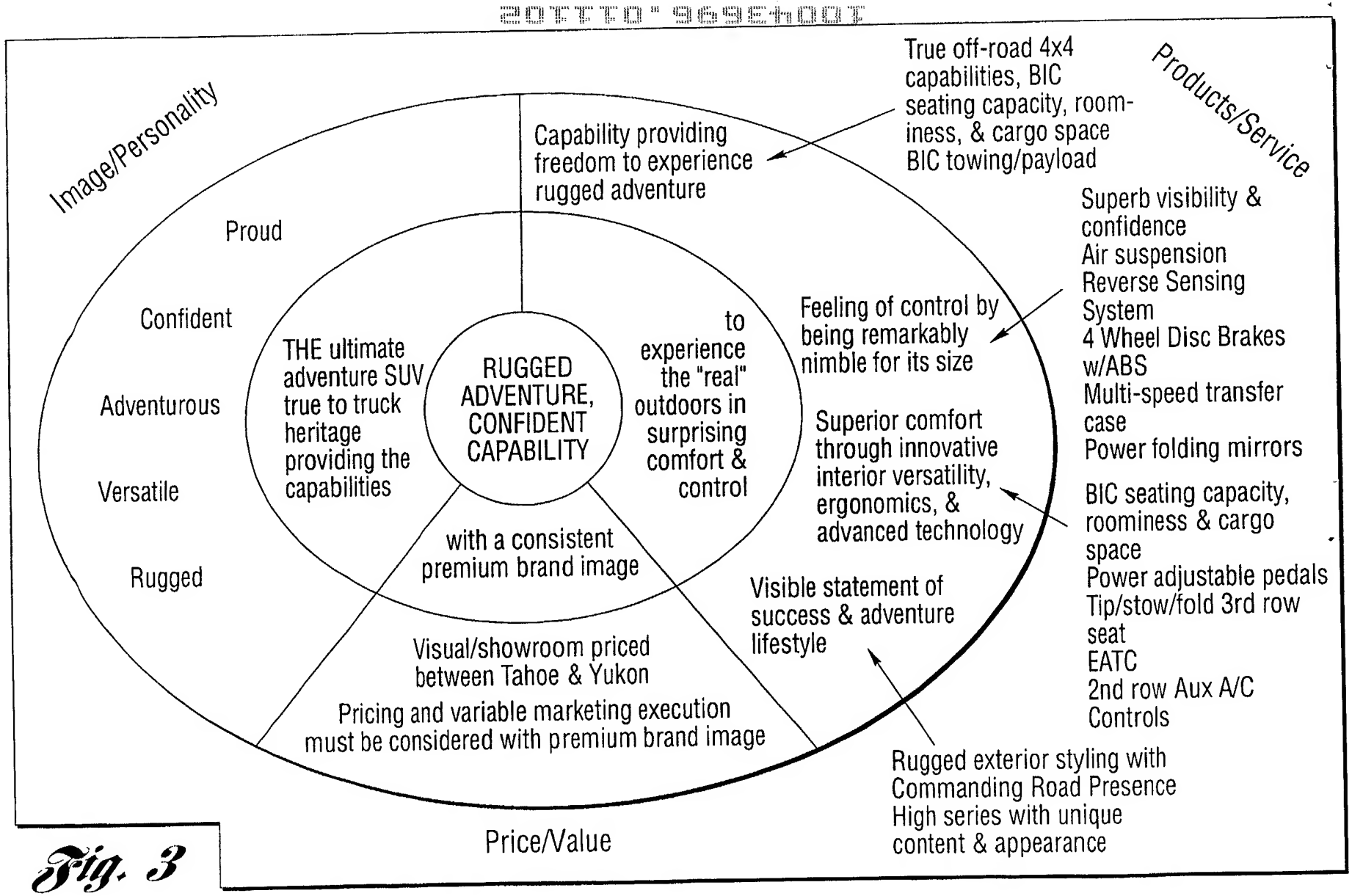

Image/Personality
Products/Service
Price/Value
Proud
Confident
Adventurous
Versatile
Rugged
Capability providing freedom to experience rugged adventure
True off-road 4x4 capabilities, BIC seating capacity, roominess, & cargo space
BIC towing/payload
Superb visibility & confidence
Air suspension
Reverse Sensing System
4 Wheel Disc Brakes w/ABS
Multi-speed transfer case
Power folding mirrors
Feeling of control by being remarkably nimble for its size
Superior comfort through innovative interior versatility, ergonomics, & advanced technology
BIC seating capacity, roominess & cargo space
Power adjustable pedals
Tip/stow/fold 3rd row seat
EATC
2nd row Aux A/C Controls
THE ultimate adventure SUV true to truck heritage providing the capabilities
RUGGED ADVENTURE, CONFIDENT CAPABILITY
to experience the "real" outdoors in surprising comfort & control
with a consistent premium brand image
Visible statement of success & adventure lifestyle
Visual/showroom priced between Tahoe & Yukon
Pricing and variable marketing execution must be considered with premium brand image
Rugged exterior styling with Commanding Road Presence
High series with unique content & appearance

Fig. 3

BRAND PROFILER
PRODUCT ATTRIBUTE
LEADERSHIP STRATEGY

40

42

ATTRIBUTE	ATTRIBUTE CLASS	PRIORITY (RANK)	PRIMARY BRAND POSITIONING	NAMEPLATE BRAND POSITIONING	PROGRAM SPECIFICS		PRESENT NAMEPLATE ENTRY
					TARGET OBJECTIVES	STATUS	
USAGE EXPERIENCE							
INTERIOR ROOMINESS	D	1	(L) A C M	(L) A C M	L A C M	L A C M	(L) A C U
ERGONOMICS/FLEXIBILITY/ COMFORT	D	2	L (A) C M	(L) A C M	L A C M	L A C M	(L) A C U
LUGGAGE/CARGO SPACE	D	3	(L) A C M	(L) A C M	L A C M	L A C M	L (A) C U
DURABILITY/CRAFTMANSHIP	D	6	L (A) C M	L (A) C M	L A C M	L A C M	L (A) C U
QUIETNESS	I	8	L (A) C M	L (A) C M	L A C M	L A C M	L (A) C U
EASE OF ENTRY/EXIT	I	11	L (A) C M	L (A) C M	L A C M	L A C M	L (A) C U
RANGE/FUEL ECONOMY	G	15	L (A) C M	L (A) C M	L A C M	L A C M	L (A) C U
CLIMATE CONTROL	G	17	(L) A C M	L A (C) M	L A C M	L A C M	(L) A C U
EXTERIOR VISIBILITY	G	20	L (A) C M	L A (C) M	L A C M	L A C M	(L) A C U
COST OF OWNERSHIP	G	25	(L) A C M	L A (C) M	L A C M	L A C M	L (A) C U
DRIVING EXPERIENCE							
PERFORMANCE/TOWING	D	4	L (A) C M	(L) A C M	L A C M	L A C M	(L) A C U
RIDE	I	9	L (A) C M	L (A) C M	L A C M	L A C M	L (A) C U

Fig. 4

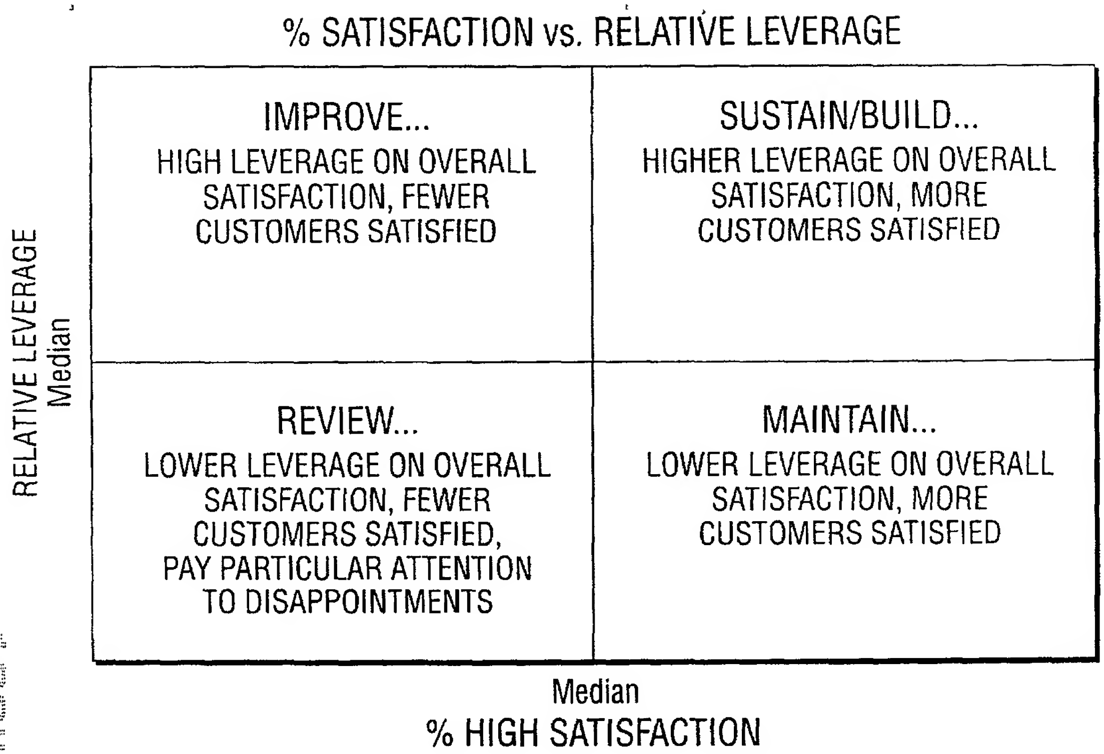

% SATISFACTION vs. RELATIVE LEVERAGE
IMPROVE...
HIGH LEVERAGE ON OVERALL SATISFACTION, FEWER CUSTOMERS SATISFIED
SUSTAIN/BUILD...
HIGHER LEVERAGE ON OVERALL SATISFACTION, MORE CUSTOMERS SATISFIED
REVIEW...
LOWER LEVERAGE ON OVERALL SATISFACTION, FEWER CUSTOMERS SATISFIED, PAY PARTICULAR ATTENTION TO DISAPPOINTMENTS
MAINTAIN...
LOWER LEVERAGE ON OVERALL SATISFACTION, MORE CUSTOMERS SATISFIED
RELATIVE LEVERAGE
Median
Median
% HIGH SATISFACTION

Fig. 5

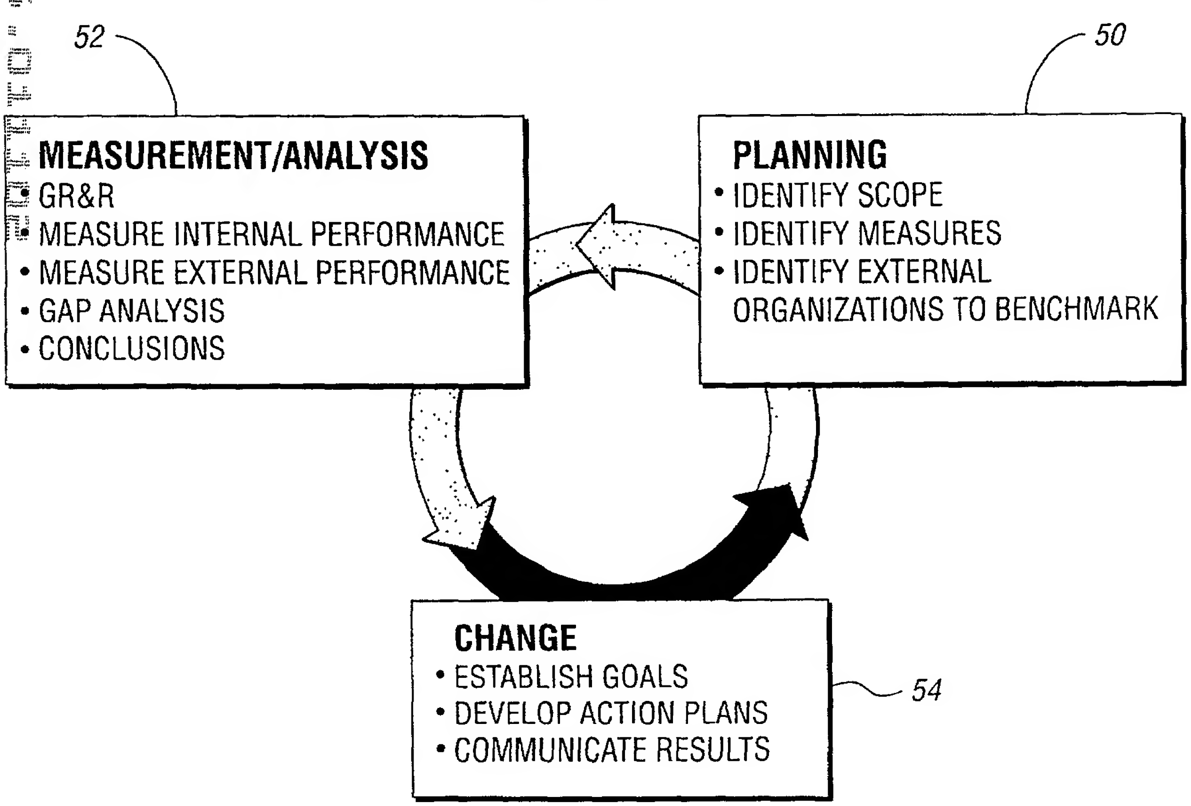

52
50
MEASUREMENT/ANALYSIS
• GR&R
• MEASURE INTERNAL PERFORMANCE
• MEASURE EXTERNAL PERFORMANCE
• GAP ANALYSIS
• CONCLUSIONS
PLANNING
• IDENTIFY SCOPE
• IDENTIFY MEASURES
• IDENTIFY EXTERNAL ORGANIZATIONS TO BENCHMARK
CHANGE
• ESTABLISH GOALS
• DEVELOP ACTION PLANS
• COMMUNICATE RESULTS
54

Fig. 6

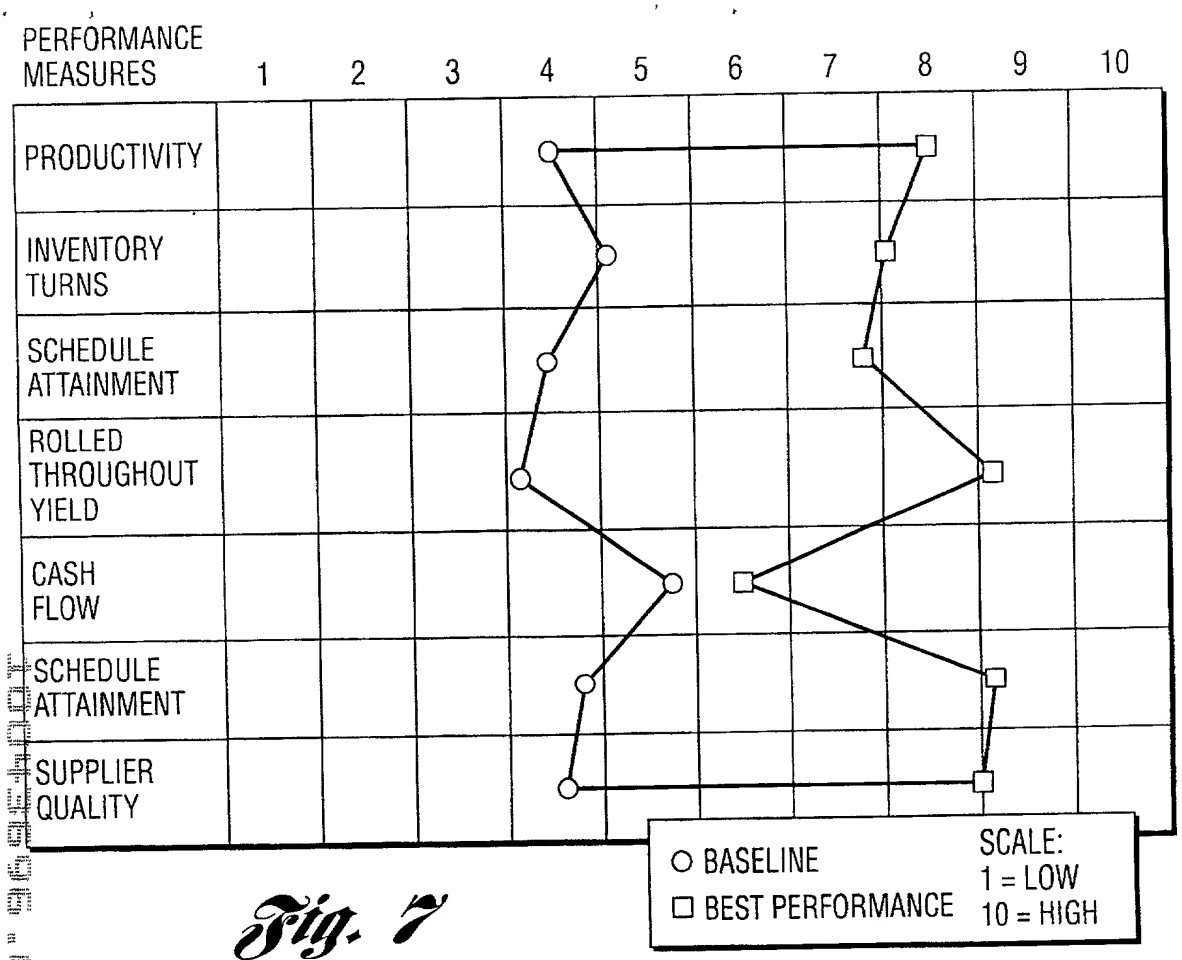

PERFORMANCE MEASURES
1
2
3
4
5
6
7
8
9
10
PRODUCTIVITY
INVENTORY TURNS
SCHEDULE ATTAINMENT
ROLLED THROUGHOUT YIELD
CASH FLOW
SCHEDULE ATTAINMENT
SUPPLIER QUALITY
BASELINE
BEST PERFORMANCE
SCALE:
1 = LOW
10 = HIGH

Fig. 7

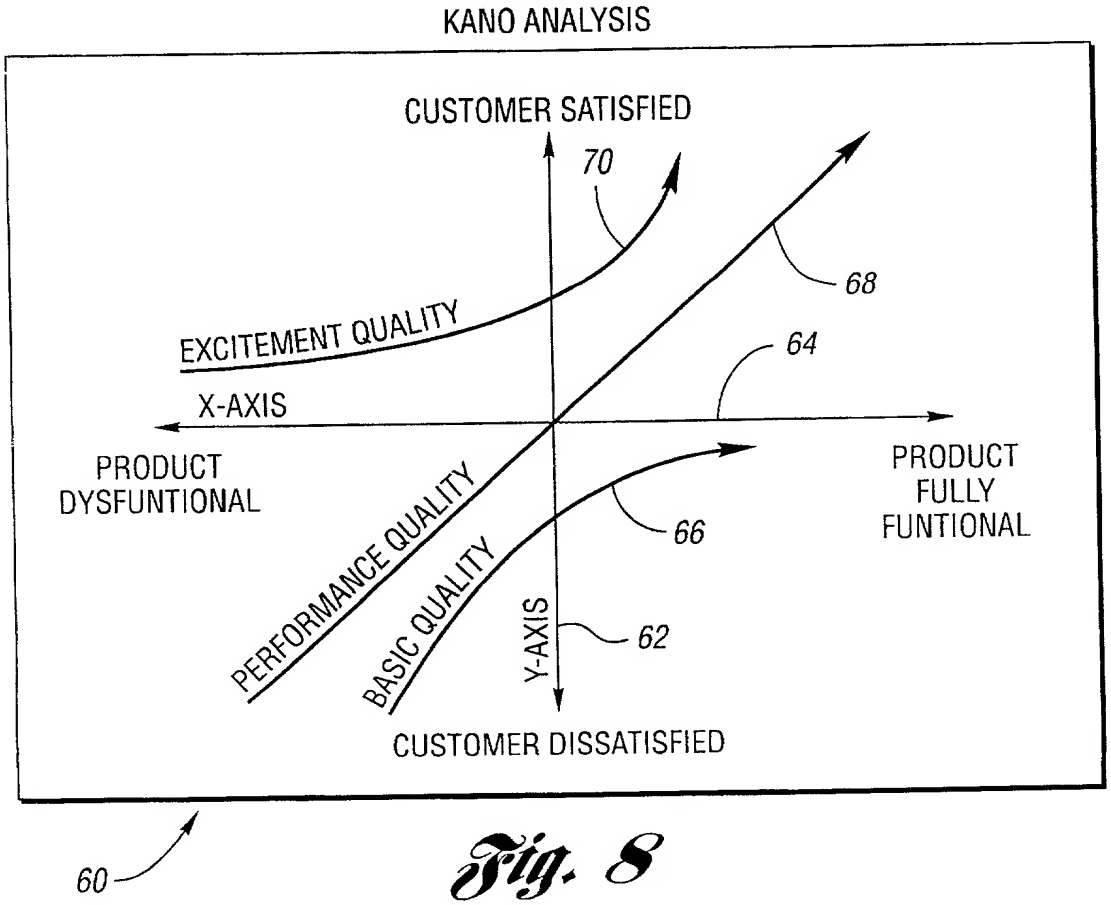

KANO ANALYSIS
CUSTOMER SATISFIED
70
68
EXCITEMENT QUALITY
64
X-AXIS
PRODUCT DYSFUNTIONAL
PRODUCT FULLY FUNTIONAL
PERFORMANCE QUALITY
BASIC QUALITY
66
Y-AXIS
62
CUSTOMER DISSATISFIED
60

Fig. 8

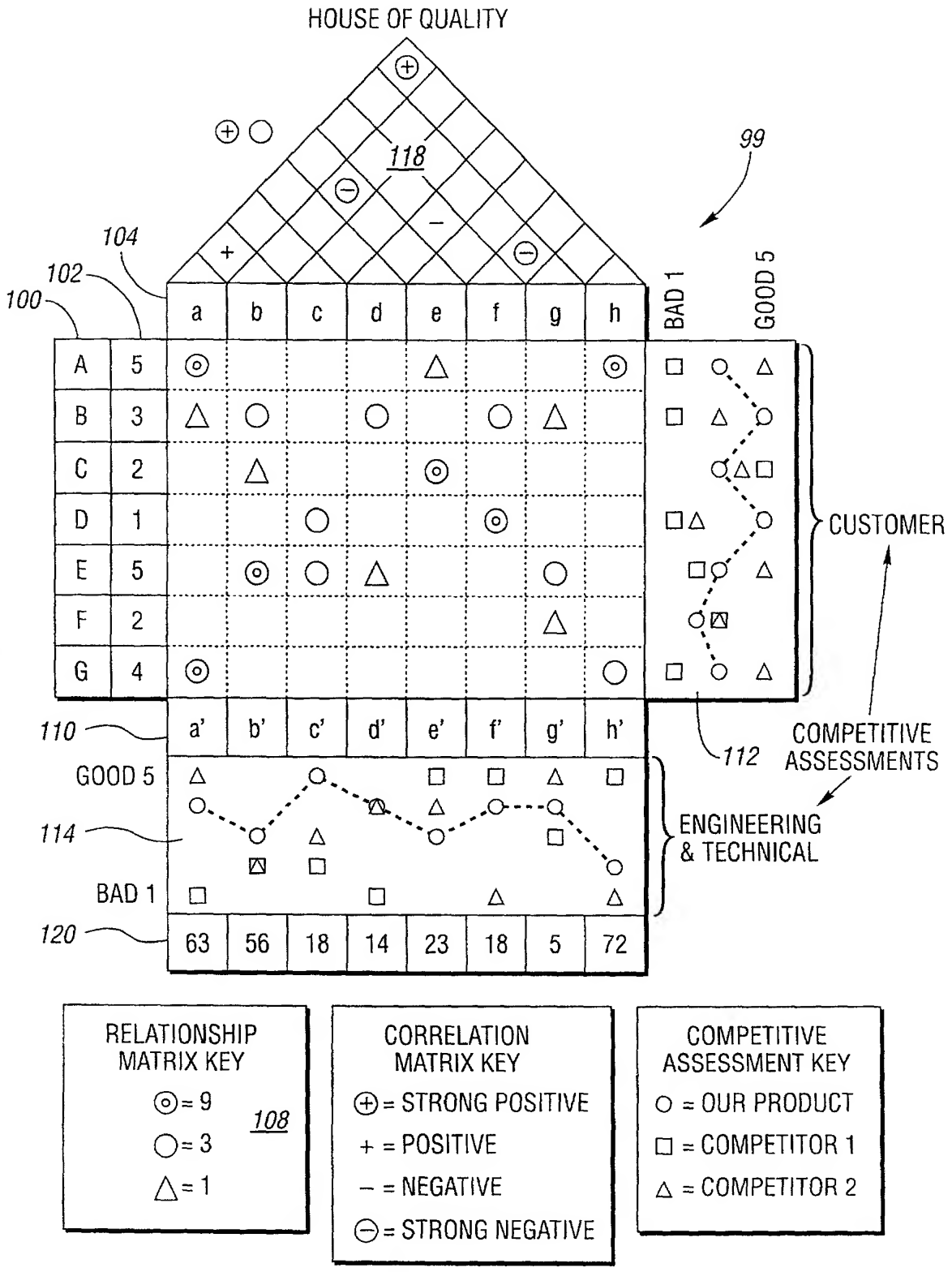

HOUSE OF QUALITY
99
118
104
102
100
a b c d e f g h
BAD 1
GOOD 5
A 5
B 3
C 2
D 1
E 5
F 2
G 4
CUSTOMER
110
a' b' c' d' e' f' g' h'
112
COMPETITIVE ASSESSMENTS
GOOD 5
114
ENGINEERING & TECHNICAL
BAD 1
120
63 56 18 14 23 18 5 72
RELATIONSHIP MATRIX KEY
⊙ = 9
◯ = 3
△ = 1
108
CORRELATION MATRIX KEY
⊕ = STRONG POSITIVE
+ = POSITIVE
– = NEGATIVE
⊖ = STRONG NEGATIVE
COMPETITIVE ASSESSMENT KEY
○ = OUR PRODUCT
□ = COMPETITOR 1
△ = COMPETITOR 2

Fig. 9

Critical to Satisfaction (CTS) Scorecard

Attribute: _____

Project Description: _____

Status of Items Critical to Satisfaction and Relationship to Customer

CTS or Surrogate	Units	T.F. ? Y/N	Status		Competitor/BIC		Target: initial Condition			Target: Aged			Associated Cust. Sat. Improvement
			mean: μ	s.d.: σ	mean: μ	s.d.: σ	mean: μ	LSL	USL	mean: μ	LSL	USL	
140	*142*	*144*	*146a*	*146b*	*148a*	*148b*	*150a*	*150b*	*150c*	*152a*	*152b*	*152c*	*154*

Fig. 10

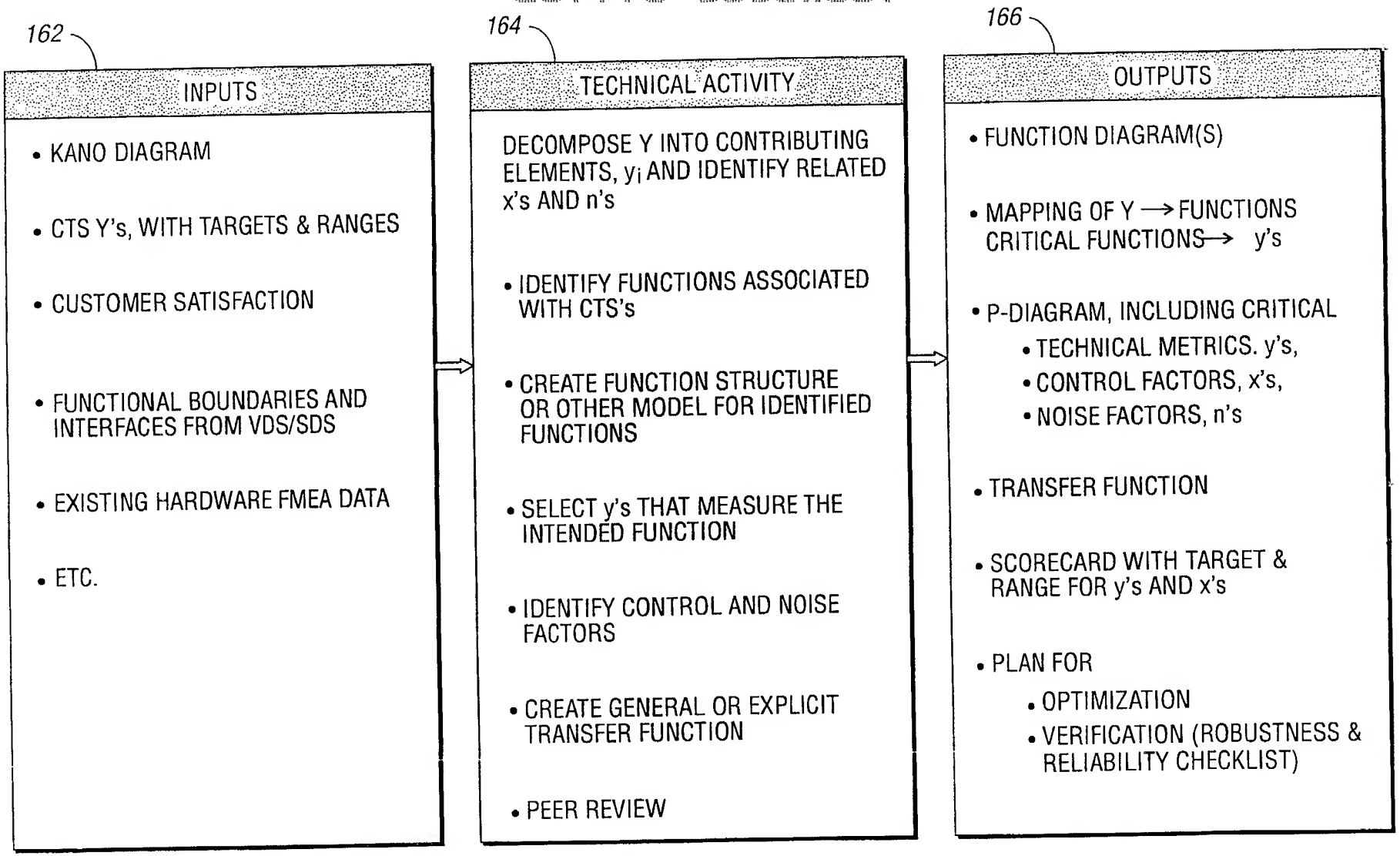

162
INPUTS
• KANO DIAGRAM
• CTS Y's, WITH TARGETS & RANGES
• CUSTOMER SATISFACTION
• FUNCTIONAL BOUNDARIES AND INTERFACES FROM VDS/SDS
• EXISTING HARDWARE FMEA DATA
• ETC.
164
TECHNICAL ACTIVITY
DECOMPOSE Y INTO CONTRIBUTING ELEMENTS, y_i AND IDENTIFY RELATED x's AND n's
• IDENTIFY FUNCTIONS ASSOCIATED WITH CTS's
• CREATE FUNCTION STRUCTURE OR OTHER MODEL FOR IDENTIFIED FUNCTIONS
• SELECT y's THAT MEASURE THE INTENDED FUNCTION
• IDENTIFY CONTROL AND NOISE FACTORS
• CREATE GENERAL OR EXPLICIT TRANSFER FUNCTION
• PEER REVIEW
166
OUTPUTS
• FUNCTION DIAGRAM(S)
• MAPPING OF Y → FUNCTIONS
CRITICAL FUNCTIONS → y's
• P-DIAGRAM, INCLUDING CRITICAL
• TECHNICAL METRICS. y's,
• CONTROL FACTORS, x's,
• NOISE FACTORS, n's
• TRANSFER FUNCTION
• SCORECARD WITH TARGET & RANGE FOR y's AND x's
• PLAN FOR
• OPTIMIZATION
• VERIFICATION (ROBUSTNESS & RELIABILITY CHECKLIST)
160

Fig. 11

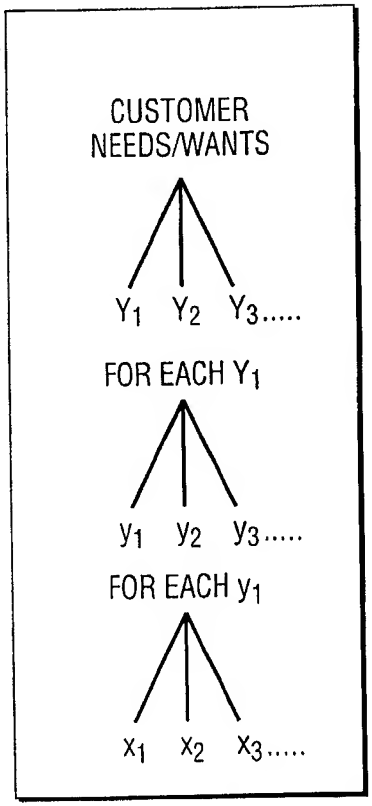


Fig. 12a

UNDERSTAND SYSTEM	FUNCTION MAPPING
Y ⟶ FUNCTIONS ⟶ y	y ⟶ f(x,n)
• MODELING FUNCTION • FUNCTIONS VERSUS CONSTRAINTS • FUNCTION STRUCTURES • ACTIVITY DIAGRAMS • FLOW CHAINS • Y-FUNCTION MATRIX • FUNCTION-FUNCTION MATRIX • TECHNICAL MATRIX: y's • FUNCTIONAL MEASUREMENT • UPDATE Y-y MATRIX (QFD)	• FACTORS: x's AND n's • AREA ANALYSIS • EXPLORATORY EXPERIMENTATION • CORRELATION • TRANSFER FUNCTIONS • AREA ANALYSIS • REGRESSION • FLOW ANALYSIS ANALYSIS CAE TOOLS • ESTABLISHING CRITICAL x's • P-DIAGRAMMING • CORRELATION • SENSITIVITY ANALYSIS

Fig. 12b

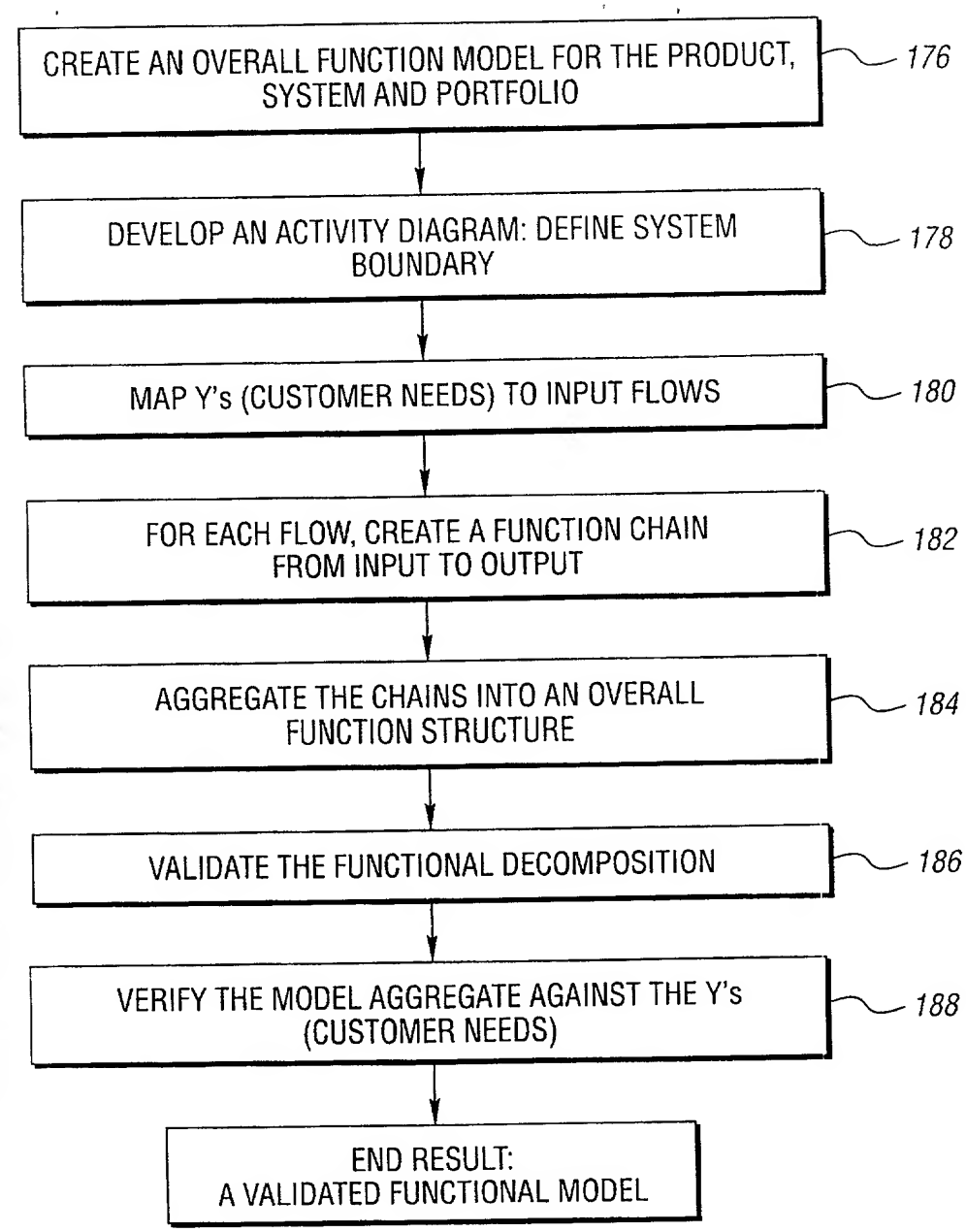

CREATE AN OVERALL FUNCTION MODEL FOR THE PRODUCT, SYSTEM AND PORTFOLIO
176
DEVELOP AN ACTIVITY DIAGRAM: DEFINE SYSTEM BOUNDARY
178
MAP Y's (CUSTOMER NEEDS) TO INPUT FLOWS
180
FOR EACH FLOW, CREATE A FUNCTION CHAIN FROM INPUT TO OUTPUT
182
AGGREGATE THE CHAINS INTO AN OVERALL FUNCTION STRUCTURE
184
VALIDATE THE FUNCTIONAL DECOMPOSITION
186
VERIFY THE MODEL AGGREGATE AGAINST THE Y's (CUSTOMER NEEDS)
188
END RESULT: A VALIDATED FUNCTIONAL MODEL
174

Fig. 13

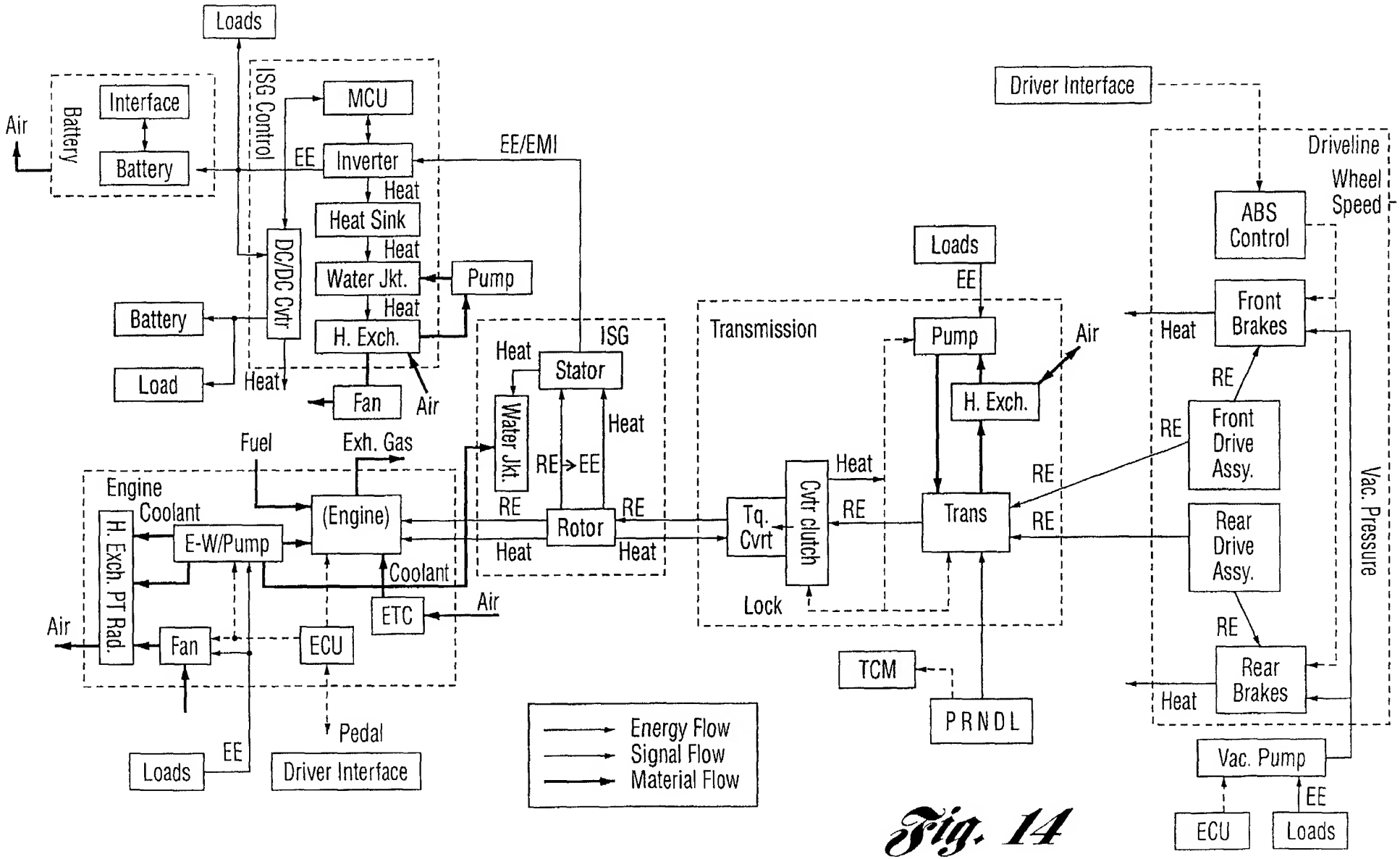

Loads
Air
Battery
Interface
Battery
ISG Control
MCU
EE
Inverter
EE/EMI
Heat
Heat Sink
Heat
Water Jkt.
Pump
Heat
H. Exch.
DC/DC Cvtr
Battery
Load
Heat
Fan
Air
Heat
Stator
ISG
Water Jkt.
RE→EE
Heat
Fuel
Exh. Gas
Engine
Coolant
H. Exch. PT Rad.
E-W/Pump
(Engine)
RE
Rotor
RE
Heat
Heat
Coolant
ETC
Air
Air
Fan
ECU
Pedal
Loads
EE
Driver Interface
Transmission
Loads
EE
Pump
Air
H. Exch.
Heat
Tq. Cvtr
Cvtr clutch
RE
Trans
RE
RE
Lock
TCM
PRNDL
Driver Interface
Driveline
Wheel Speed
ABS Control
Heat
Front Brakes
RE
RE
Front Drive Assy.
RE
Rear Drive Assy.
RE
Heat
Rear Brakes
Vac. Pressure
Vac. Pump
EE
ECU
Loads
Energy Flow
Signal Flow
Material Flow

Fig. 14

TRANSFER FUNCTIONS

- A QUANTITIVE RELATIONSHIP BETWEEN DEPENDENT AND INDEPENDENT VARIABLES THAT CAN BE EXPRESED AS AN EQUATION OF THE FORM

$$\left.\begin{array}{c} Y = F(y_1, \ldots., y_n) \\ \text{OR} \\ y = f(x_1, \ldots., x_n) \end{array}\right\} 190$$

- ACTUAL TRANSFER FUNCTION MAY LOOK SOMETHING LIKE THIS

$$\left.\begin{array}{c} Y = \alpha \sin y_1 + \beta \cos y_2 + \gamma y_3, \\ y = \beta_0 + \beta_1 x_1^{\alpha_1} + \beta_2 x_2^{\alpha_2} + \beta_3 x_3^{\alpha_3} + \lambda_1 n_1, \\ \text{etc.} \end{array}\right\} 192$$

Fig. 15

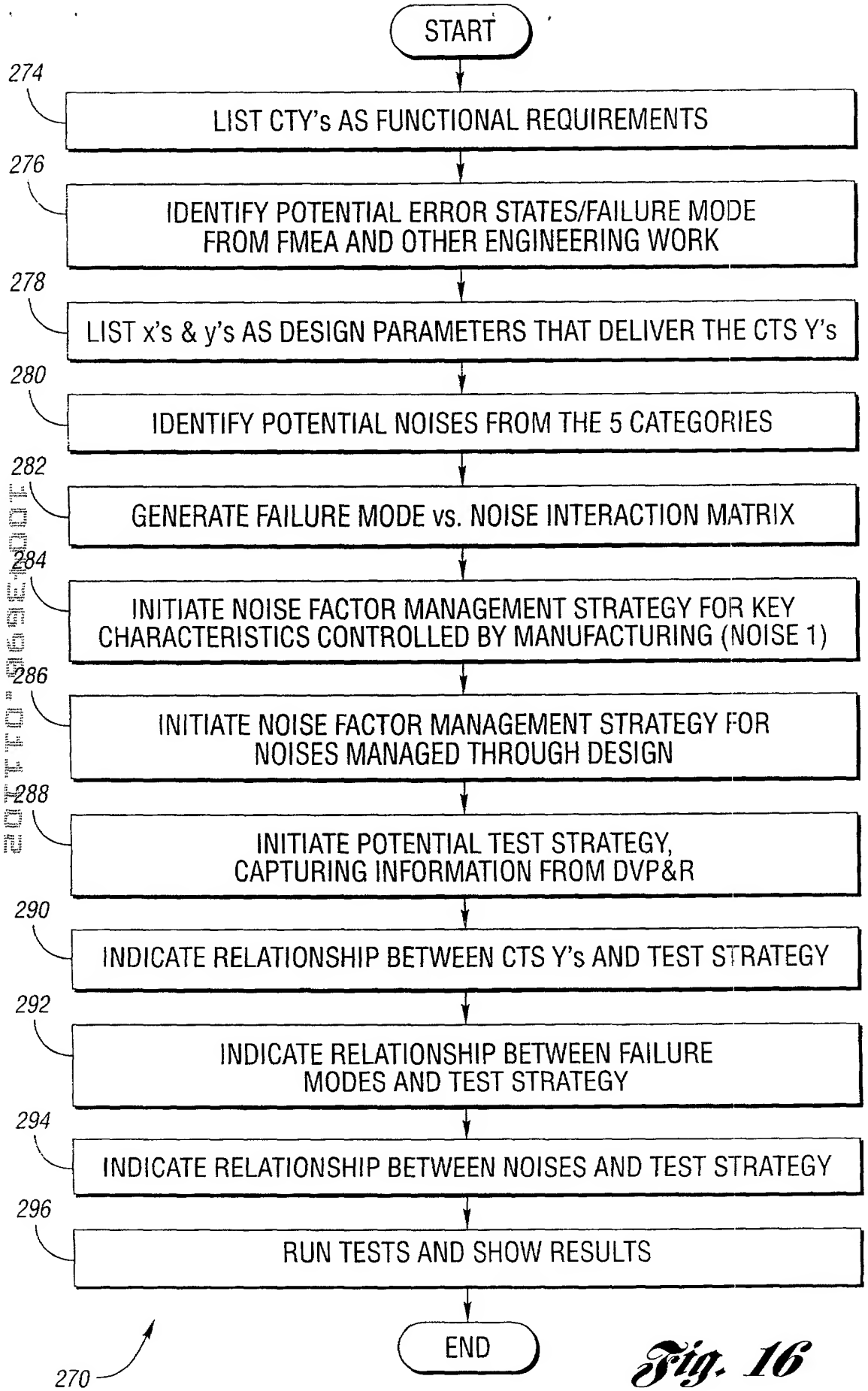

START
274
LIST CTY's AS FUNCTIONAL REQUIREMENTS
276
IDENTIFY POTENTIAL ERROR STATES/FAILURE MODE FROM FMEA AND OTHER ENGINEERING WORK
278
LIST x's & y's AS DESIGN PARAMETERS THAT DELIVER THE CTS Y's
280
IDENTIFY POTENTIAL NOISES FROM THE 5 CATEGORIES
282
GENERATE FAILURE MODE vs. NOISE INTERACTION MATRIX
284
INITIATE NOISE FACTOR MANAGEMENT STRATEGY FOR KEY CHARACTERISTICS CONTROLLED BY MANUFACTURING (NOISE 1)
286
INITIATE NOISE FACTOR MANAGEMENT STRATEGY FOR NOISES MANAGED THROUGH DESIGN
288
INITIATE POTENTIAL TEST STRATEGY, CAPTURING INFORMATION FROM DVP&R
290
INDICATE RELATIONSHIP BETWEEN CTS Y's AND TEST STRATEGY
292
INDICATE RELATIONSHIP BETWEEN FAILURE MODES AND TEST STRATEGY
294
INDICATE RELATIONSHIP BETWEEN NOISES AND TEST STRATEGY
296
RUN TESTS AND SHOW RESULTS
END
270

Fig. 16

PROGRAM

System/Sub-system/Component

Reliability & Robustness Checklist

Design Parameters									
1	2	3	4	5	6	7	8	9	10
				302					

Test Name CAE/Comp./Subsyst./System/Vehicle								
1	2	3	4	5	6	7	8	9
				312				

Functional Requirement Life Target (for the subject component/system)

CTS # 1:
CTS # 2:
CTS # 3:
CTS # 4: 298
CTS # 5:
CTS # 6:
CTS # 7:
CTS # 9:

304

314

ERROR STATES/FAILURE MODE -potential TGW, negated function and/or "Noises" for other sub-systems

300

A
B
C
D
E
F
G

Show interactions between Failure Modes and Noise Factors

NOISE FACTOR MANAGEMENT

Cat	Strategy
I	Change technology
II	Apply Parameter Design
III	Upgrade Design Spec.
IV	Reduce/Remove Noise
V	Add Compensation Device
VI	Disguise/Divert

Testing Strategy Followed: i.e., Test-to-Failure, Degradation, DOE, etc...

316

Fig. 17a

NOISE 1: TOTAL DESIGN/Mfg. VARIABILITY	A	B	C	D	E	F	G	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9
Piece-to-piece variation or drawing tolerance whichever is greater and total scope applicable																										
NOISE 2: COMPONENT CHANGES OVER TIME/MILEAGE	A	B	C	D	E	F	G	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9
Change in dimension or change in strength over Useful Life Period (assumptions above)																										
NOISE 3: DUTY CYCLE/CUSTOMER USEAGE	A	B	C	D	E	F	G	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9
"Typical" Customer usage over Useful Life Period (assumption above)																										
NOISE 4: EXTERNAL ENVIRONMENT	A	B	C	D	E	F	G	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9
Climatic conditions geographic conditions																										
NOISE 5: IN VEHICLE SYSTEMS ENVIRONMENT	A	B	C	D	E	F	G	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9
Physical interfaces with associated systems or mating components over Useful Life Period (assumptions above) loads from or interaction with																										

318

306 308 310

Fig. 17b

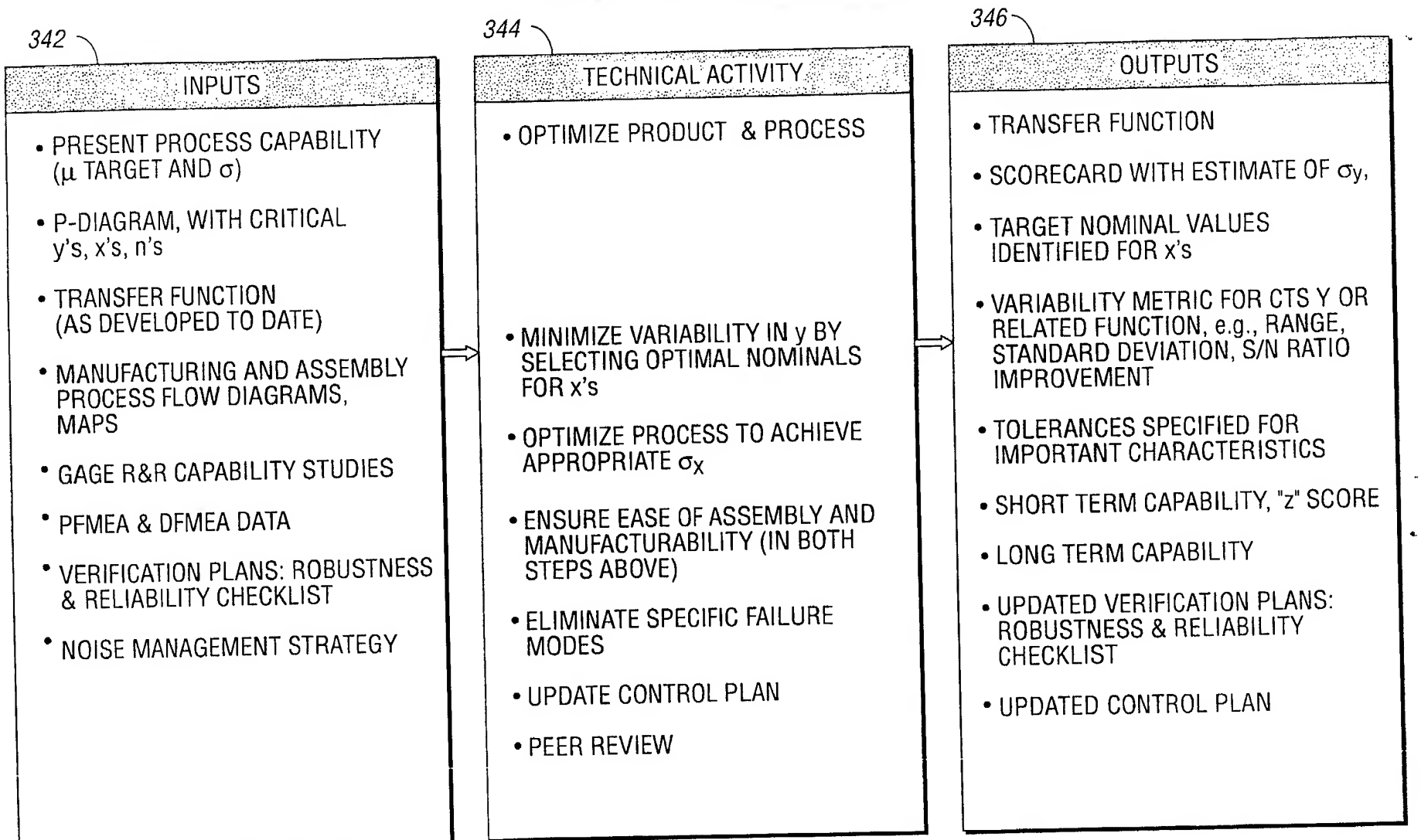
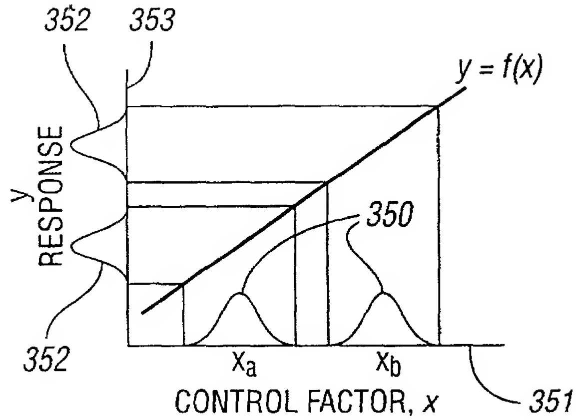

342
INPUTS
• PRESENT PROCESS CAPABILITY (μ TARGET AND σ)
• P-DIAGRAM, WITH CRITICAL y's, x's, n's
• TRANSFER FUNCTION (AS DEVELOPED TO DATE)
• MANUFACTURING AND ASSEMBLY PROCESS FLOW DIAGRAMS, MAPS
• GAGE R&R CAPABILITY STUDIES
• PFMEA & DFMEA DATA
• VERIFICATION PLANS: ROBUSTNESS & RELIABILITY CHECKLIST
• NOISE MANAGEMENT STRATEGY
344
TECHNICAL ACTIVITY
• OPTIMIZE PRODUCT & PROCESS
• MINIMIZE VARIABILITY IN y BY SELECTING OPTIMAL NOMINALS FOR x's
• OPTIMIZE PROCESS TO ACHIEVE APPROPRIATE σx
• ENSURE EASE OF ASSEMBLY AND MANUFACTURABILITY (IN BOTH STEPS ABOVE)
• ELIMINATE SPECIFIC FAILURE MODES
• UPDATE CONTROL PLAN
• PEER REVIEW
346
OUTPUTS
• TRANSFER FUNCTION
• SCORECARD WITH ESTIMATE OF σy,
• TARGET NOMINAL VALUES IDENTIFIED FOR x's
• VARIABILITY METRIC FOR CTS Y OR RELATED FUNCTION, e.g., RANGE, STANDARD DEVIATION, S/N RATIO IMPROVEMENT
• TOLERANCES SPECIFIED FOR IMPORTANT CHARACTERISTICS
• SHORT TERM CAPABILITY, "z" SCORE
• LONG TERM CAPABILITY
• UPDATED VERIFICATION PLANS: ROBUSTNESS & RELIABILITY CHECKLIST
• UPDATED CONTROL PLAN
340

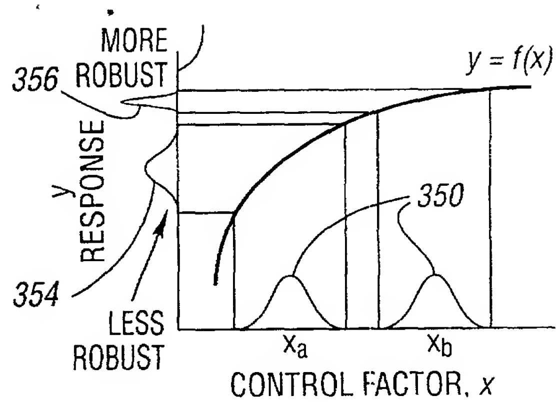
Fig. 18



"SHIFT"

- WHEN f(x) IS LINEAR, THE NOMINAL VALUE OF THE CONTROL FACTOR x HAS NO EFFECT ON THE VARIABILITY OF THE RESPONSE, f(x).
- CHANGE THE LEVEL OF THIS CONTROL FACTOR TO SHIFT THE RESPONSE WITHOUT AFFECTING VARIABILITY.

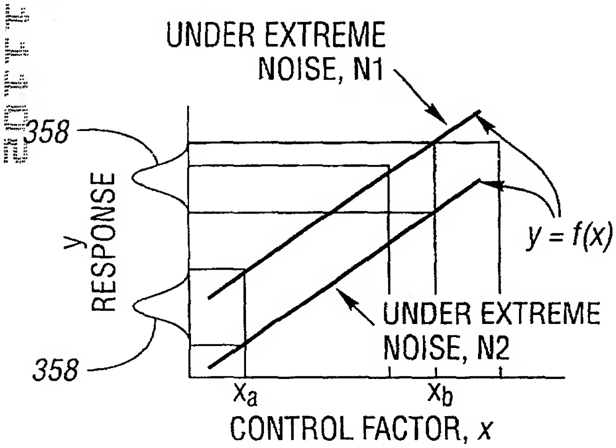
Fig. 19a



"SHRINK"

- WHEN f(x) IS NON-LINEAR, THE NOMINAL VALUE OF THE CONTROL FACTOR x CAN HAVE A MAJOR EFFECT ON THE VARIABILITY OF THE RESPONSE, f(x).
- CHANGE THE LEVEL OF THIS CONTROL FACTOR TO DESENSITIZE THE RESPONSE TO THE CONTROL FACTOR VARIABILITY.

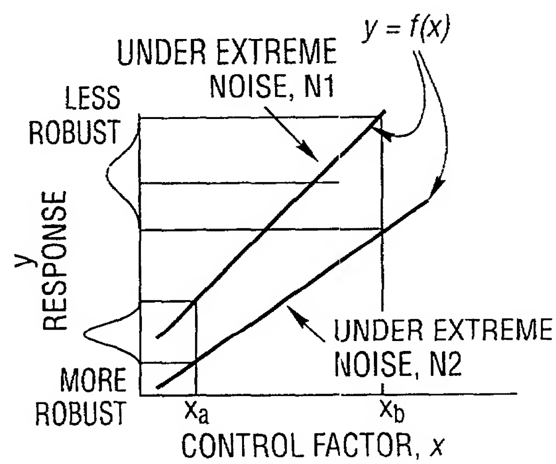
Fig. 19b



"SHIFT"

- WHEN THE CONTROL FACTOR x DOES NOT INTERACT WITH THE NOISE, THE NOMINAL VALUE OF x HAS NO EFFECT ON THE RESPONSE VARIABILITY.
- CHANGE THE LEVEL OF THIS CONTROL FACTOR TO SHIFT THE RESPONSE WITHOUT AFFECTING VARIABILITY.

Fig. 20a



"SHRINK"

- WHEN THE CONTROL FACTOR x INTERACTS WITH THE NOISE, THE NOMINAL VALUE OF x CAN HAVE A MAJOR EFFECT ON RESPONSE VARIABILITY.
- CHANGE THE LEVEL OF THIS CONTROL FACTOR TO DESENSITIZE PERFORMANCE TO THE NOISE AND SHRINK THE RESPONSE VARIABILITY.

Fig. 20b

Vehicle/Part Name: 5.4L Engine Compression Ration
Description: Compression Ration Contribution to Engine Quietness

Performance		Transfer Function	
Characteristic	Units	Y/N	Formula (enter here)
CR	Ratio	Y	y = f(x, n)

372 380 374 382 376

Variables			Range		Contribution
No.	Characteristic	Units	Min	Max	Sensitivity
1	Cyl Hd Cmbr Vol	cc			-0.27
2	Blk Dk Crk/Deck Cl	mm	255.91	256.04	-0.12
3	Head Gasket Thk	mm	0.97	1.06	-0.055
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Cell Shading Key

	Enter Data
	Do not enter data (Calculation)

Confidence Ratings

High (H)	Estimate based on customer-correlated model of same parts
Med (M)	Estimate based on partial customer correlation or surrogate parts
Low (L)	Estimate without customer correlation or no process data available

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Fig. 21a

Specification			Predicted Performance Capability			
Target	LSL	USL	mean: μ	s.d.: σ	Short/Long	Confidence
9	8.85	9.15	8.898125	0.094551	Short	High

x's, Input Control Factors						
to Variability	Specification		Sample/Database Statistics			
%	LSL	USL	mean: μ	s.d.: σ	Short/Long	Confidence
99.89%	42.45	45.45	44.36	0.35	short	H
0.09%	255.875	256.125	255.924	0.02403	short	H
0.02%	0.9	1.12	1.01536	0.02146	short	H
n's, Input Control Factors						

	Enter Formula (must refer to cells J13, J14, ... representing x_1, x_2, ...)
	Do not enter data (Not applicable for Noise Factors)

Fig. 21b

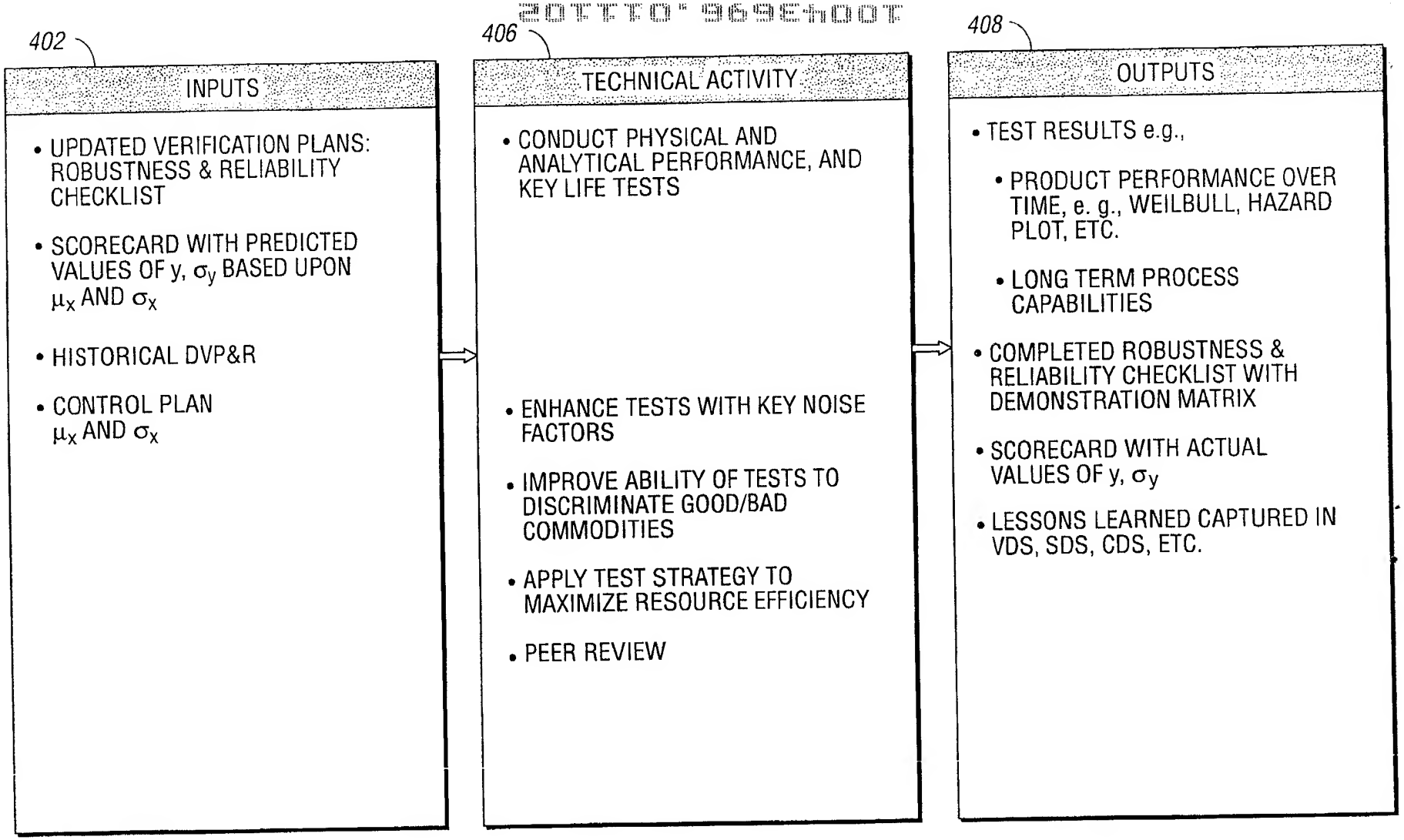

Fig. 22